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(71) Applicant: Marconi Medical Systems, Inc.
Cleveland, Ohio 44143 (US)

(72) Inventors:
- Steckner, Michael
  Richmond Heights, Ohio 44143 (US)
- Ruohonen, Jarmo O.
  01650 Vantaa (FI)
- Demeester, Gordon D.
  Wickliffe, Ohio 44092 (US)
- Carlson, Robert K.
  Willoughby, Ohio 44094 (US)

(74) Representative: Waters, Jeffrey
Marconi Intellectual Property Marrable House
The Vineyards Gt. Baddow
Chelmsford Essex CM2 7QS (GB)

(54) External patient contouring

(57) An open MRI or other diagnostic imaging system (A) generates a three-dimensional diagnostic image representation, which is stored in an MRI image memory (26). A laser scanner or other surface imaging system (B) generates a volumetric surface image representation that is stored in a surface image memory (34). Typically, the volume and surface images are misaligned and the magnetic resonance image may have predictable distortions. An image correlating system (C) determines offset, scaling, rotational, and non-linear corrections to the magnetic resonance image representation, which are implemented by an image correction processor (48). The corrected magnetic resonance image representation and the surface image representation are combined (50) and stored in a superimposed image memory (52). A video processor (54) generates image representations from selected portions of the superimposed image representation for display on a human-readable monitor (56).

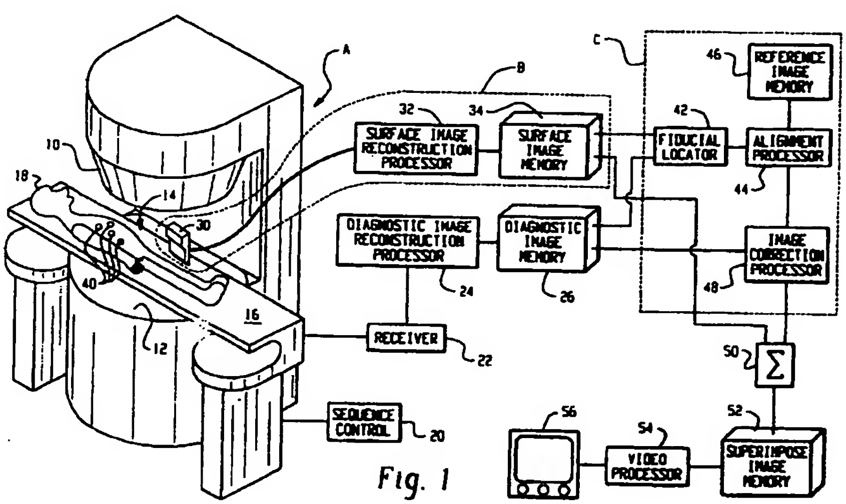

Fig. 1

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Description

[0001] The present invention relates to the field of imaging. It finds particular application in conjunction with diagnostic imaging in open MRI scanners for oncology treatment applications and will be described with particular reference thereto. It will be appreciated, however, that the invention is also applicable to other types of diagnostic imaging for oncological purposes and for imaging for other purposes.

[0002] In oncological planning, the oncologist typically determines a point of entry on the patient's skin and a trajectory through the patient. Typically, the oncologist plans a trajectory and the point of entry in conjunction with projection x-ray images, CT scanner images, or other diagnostic images.

[0003] One of the difficulties encountered in oncological procedures is accurately aligning the x-ray beam with the internal tumor. If the selected trajectory is only slightly off, the x-ray beam will treat most of the tumor, but leave a small segment un-irradiated. Un-irradiated tumor tissue can survive the treatment.

[0004] Once the point of entry and the trajectory have been determined, the oncologist points an x-ray beam to enter the patient at the selected point of entry and follow the selected trajectory. Ideally, the x-ray beam is selected to have a diameter at least as large as the tumor to be irradiated. Making the diameter of the beam too large is detrimental in that it irradiates and harms healthy tissue.

[0005] Typically, the treatment process is repeated through a plurality of different trajectories to maximize the radiation at the tumor while minimizing radiation through surrounding tissue. In many instances, the tumor is over-irradiated to assure that portions of the tumor which might be missed along some trajectories are still fully irradiated. This over-radiation, like using a beam that is too large, has a detrimental effect on surrounding tissue.

[0006] Typically, x-ray images are used to generate the diagnostic images. X-ray images are advantageous in that they image the entire patient contour, including the surface boundaries facilitating selection of the point of entry. Unfortunately, it is sometimes difficult to differentiate between tissue types, such as cancerous and non-cancerous tissue with x-rays. Magnetic resonance imaging has much better differentiation of tissue types. However, magnetic resonance images tend to be of smaller, internal regions and often do not include the patient surface. When a larger region is imaged that includes the patient surface, peripheral portions of the image tend to be warped or distorted. Selecting the point of entry based on a warped or distorted image can cause mis-alignment between the beam and the cancerous tumor which, as discussed previously, can create the unwanted destruction of healthy tissue.

[0007] In accordance with one aspect of the present invention, a diagnostic imaging system is provided. A medical diagnostic imaging apparatus generates volumetric diagnostic image representations of an internal region of a subject in an imaging region. A surface imaging system generates a three-dimensional image representation of the surface of the subject in the imaging region. An image correlating system correlates the surface and diagnostic image representations. A superimposed volumetric image representation memory stores combined correlated surface and diagnostic image representations. A video processor withdraws selected portions of the combined image representation and converts them into appropriate form for human-readable display.

[0008] In accordance with another aspect of the present invention, a method of diagnostic imaging is provided. A volumetric diagnostic image representation of an internal region of a subject and at least a portion of a surface of the subject is generated. However, the diagnostic image representation has distortions, particularly in a region adjacent the surface of the subject. A surface imaging system generates a three-dimensional image representation of the surface of the subject. The diagnostic image representation is adjusted to correlate at least the surface region of the diagnostic image representation with the surface image representation. The adjusted diagnostic image representation and the surface image representation are combined.

[0009] One advantage of the present invention is that it permits improved differentiation of soft tissue.

[0010] Another advantage of the present invention is that it facilitates a reduction in radiation doses in oncological treatments.

[0011] Another advantage of the present invention is that it facilitates location of internal patient structures from the exterior of the patient based on diagnostic images.

[0012] Another advantage of the present invention is that it reduces total patient radiation dose relative to x-ray and CT diagnostic imaging techniques.

[0013] One way of carrying out the invention will now be described in detail, by way of example, with reference to the accompanying drawing (Figure 1), which is a diagrammatic illustration of an image generation system in accordance with the present invention.

[0014] With reference to FIGURE 1, a medical diagnostic imaging apparatus A, such as an open magnetic resonance imaging system, generates a volumetric image of an internal region of the patient including a portion of the patient surface. A surface imaging system B generates a volumetric image of the patient surface. An imaging correlating system C scales, shifts, rotates, and non-linearly adjusts the medical diagnostic image to bring it into correlation with the surface image representation. The correlated images are combined to provide a combined or superimposed image of interior and surface from which the oncologist extracts medically appropriate slice, 3D rendered, or other images for planning the oncological procedure.

[0015] The diagnostic imager **A** in the preferred embodiment is a vertical field magnetic resonance imaging system that includes an upper pole **10** and a lower pole **12.** Magnets, preferably superconducting, generate a vertical magnetic field through an imaging region **14** between the poles **10** and **12.** A patient support **16** is movable in three dimensions to position a region of interest of a subject **18** in the imaging region.

[0016] A sequence control processor **20** controls gradient and radio frequency coils associated with the poles **10, 12** of the magnetic resonance imager to induce and manipulate magnetic resonance, as is known in the art, to generate magnetic resonance signals. The generated magnetic resonance signals are picked by radio frequency coils, demodulated by a receiver **22,** and reconstructed by an MRI image reconstruction processor **24** into an electronic image representation. The electronic image representation of the region of interest of the subject disposed in the imaging region **14** is stored in an MRI volume image memory **26.**

[0017] The surface imaging system **B** in the preferred embodiment is a hand-held laser scanning system. More specifically, the laser scanning system includes a hand-held unit **30** which sweeps a laser beam. The hand-held unit **30** is positioned such that the laser beam scans the surface of the subject **18** in the imaging region **14.** The reflected laser light received by the hand-held unit **30** generates electronic signals which are conveyed to a surface image reconstruction processor **32** which reconstructs an electronic image representation of the surface of the subject **18** in three dimensions. A surface volume image memory **34** stores the electronic image representation. Other known surface imaging systems are also contemplated, such as ultrasonic imaging systems, optical imaging systems such as those with stereo cameras, mechanical arms which are moved over the surface, and the like.

[0018] In order to facilitate coordination of the surface and MRI diagnostic images, a plurality of fiducials **40** that are imageable by both the MRI imaging system and the surface imaging system, are preferably adhered to several, scattered positions on the surface of the patient in the examination region. Alternately, anatomical markers that are identifiable in both images can be utilized analogously. The image correlating system **C** includes a fiducial locating processor **42** which examines the electronic surface and diagnostic image representations to identify the fiducials **40** in each. More specifically, the fiducial locating processor **42** generates a three-dimensional image representation of the fiducials **40** in the diagnostic image. An alignment processor **44** compares the position of the fiducials in the two images. In one embodiment, the alignment processor **44** determines the baricenter of the fiducials **40** in each of the aforementioned images and determines an offset or linear shift therebetween. The alignment processor also determines the distance between the baricenter and each of the fiducials **40** in each of the aforementioned images and determines a scaling factor in accordance with the variation therebetween. The alignment processor **44** also determines rays between the baricenter and the fiducials **40** in each of the aforementioned images and determines an angular offset or rotational correction between the two. Preferably, the alignment processor **44** also accesses a reference image from a reference image memory **46** to perform higher order alignment functions. More specifically to the preferred embodiment, an image of a phantom is generated with the medical diagnostic imaging apparatus **A.** Based on differences between the known shape of the phantom and the shape of the image, non-linear distortion adjustments for the diagnostic imaging apparatus **A** are generated and stored in the reference image memory **46.**

[0019] The offset, scaling, rotational, and non-linear image corrections determined by the alignment processor **44** are conveyed to an image correction processor **48** which operates on the medical diagnostic image representation to bring it into alignment with the surface image representation.

[0020] The surface and corrected diagnostic image representations are combined **50** and stored in a superimposed volumetric image memory **52.** Under control of the oncologist, a video processor **54** selects portions of the superimposed volumetric image representation from the superimposed image memory **50** and converts them into appropriate form and format for display on a monitor **56** such as a video monitor, CCD display, active matrix, or the like. The video processor **52** may select slice images, surface renderings, projection images, or other diagnostic imaging formats as are known in the art.

[0021] In an alternate embodiment, the image alignment system uses a calibration phantom scan. A phantom, such as one with a three-dimensional grid of fiducials, is imaged with the MRI system The fiducial locator **42** locates the fiducials in the MRI image representation. The alignment processor compares the actual fiducial positions with the imaged positions and generates correction factors. The correction factors can be as discussed above, vector shifts for each of a plurality of subregions, or the like. The correction factors are loaded into the image correction processor **48.** Optionally, a similar correction factor determining procedure is performed with the surface imaging system and loaded into an analogous image correction processor for the surface volume image. When a patient is subsequently imaged, the MRI image representation and, optionally, the surface image representation, are corrected as generated with the preloaded corrections without fiducials on the patient or the on-the-fly fiducial correlation processing.

Claims

1. An imaging system comprising: an imaging apparatus (A) for generating volumetric image represen-

tations of an internal region of a subject (18) in an imaging region (14); a surface imaging system (B) for generating a three-dimensional image representation of a surface of the subject in the imaging region; an image correlating system (C) for correlating the surface and volumetric image representations; a superimposed volumetric image representation memory (52) for storing the combined, correlated surface and volumetric image representations; and a video processor (54) for withdrawing selected portions of the combined image representation, and converting them into appropriate form for human-readable display.

2. An imaging system as claimed in claim 1, further including a plurality of fiducials (40) disposed in the imaging region (14), the fiducials being arranged to be imaged by both the imaging apparatus (A) and the surface imaging system (B) such that images of the fiducials appear in both the surface image representation and the volumetric image representation and wherein the image correlating system includes: a fiducial locating processor (42) for determining a location of the fiducials in each of the surface and volumetric image representations; and an alignment processor (44) for comparing the locations of the fiducials determined by the fiducial locating processor (42) to determine a spatial deviation between the surface and volumetric image representations.

3. An imaging system as claimed in claim 2, further including: an image correction processor (48) connected with the alignment processor to correct at least one of the volumetric and surface image representations in accordance with the determined deviation between the images.

4. An imaging system as claimed in claim 2 or claim 3, wherein the alignment processor (44) further accesses a reference memory (46) which stores information indicative of non-linear distortion in the at least one of the volumetric and surface image representations and determines a non-linear image adjustment in accordance therewith.

5. A method of imaging comprising: generating a volumetric image representation of an internal region of a subject including at least a portion of a surface of the subject, which volumetric image representation is distorted in a region adjacent the subject surface; generating a surface image representation of the surface of the subject; adjusting at least the surface region of the volumetric image representation in accordance with the surface image representation; combining the surface image representation and the adjusted volumetric image representation.

6. A method as claimed in claim 5, further including: prior to generating the volumetric image representation, generating a phantom image representation of a phantom; comparing the phantom image with physical dimensions of the phantom; determining and storing correction factors in accordance with a difference between the phantom image representation and the dimensions of the phantom; the adjusting step including adjusting the volumetric image representation in accordance with the stored correction factors.

7. A method as claimed in claim 6, further including: identifying a plurality of characteristic points on the subject surface; identifying the characteristic points in the volumetric image representation and the surface image representation; and wherein the adjusting step includes: determining a variation between the locations of the characteristic points in the volumetric image representation and the surface image representation, and adjusting the volumetric image representation in accordance with both the variations and the stored correction factors.

8. A method as claimed in claim 7, further including: affixing fiducials (40) which are identifiable in both the volumetric image representation and the surface image representation to the characteristic points on the subject surface.

9. A method as claimed in claim 7 or claim 8, wherein the step of determining the variation includes: determining an offset, a scaling factor, and a rotation between the locations of the characteristic points in the volumetric and surface image representations.

10. A method of imaging as claimed in any one of claims 5 to 9, wherein the step of generating the surface image representation includes one of laser scanning, video scanning, and ultrasonic scanning of the surface of the subject.

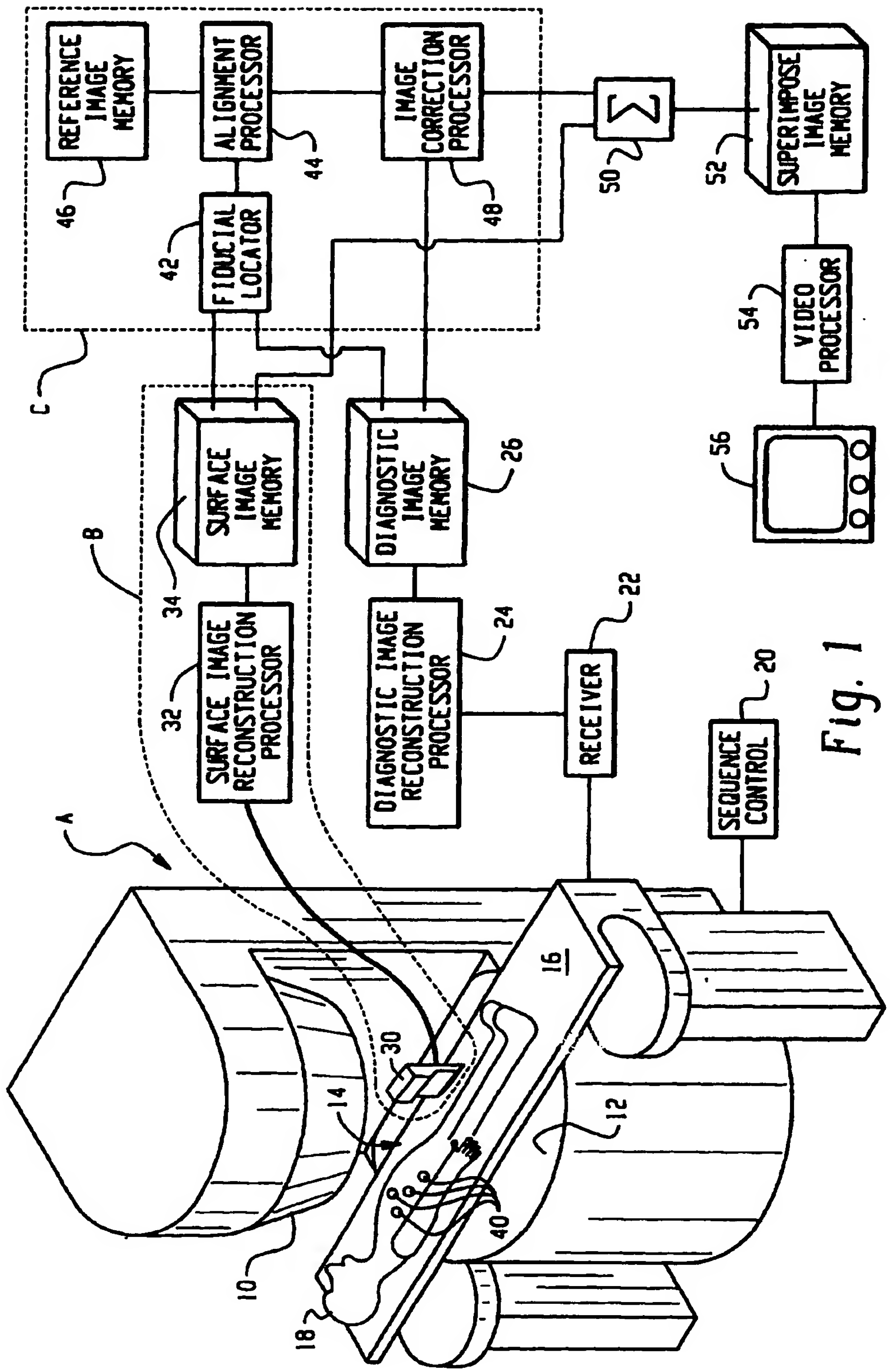
REFERENCE IMAGE MEMORY
46
ALIGNMENT PROCESSOR
44
IMAGE CORRECTION PROCESSOR
48
FIDUCIAL LOCATOR
42
C
50
SUPERIMPOSE IMAGE MEMORY
52
VIDEO PROCESSOR
54
56
B
SURFACE IMAGE MEMORY
34
DIAGNOSTIC IMAGE MEMORY
26
SURFACE IMAGE RECONSTRUCTION PROCESSOR
32
DIAGNOSTIC IMAGE RECONSTRUCTION PROCESSOR
24
RECEIVER
22
SEQUENCE CONTROL
20
A
30
14
16
12
40
10
18

Fig. 1